

IN THE CLAIMS**CLAIMS**

What is claimed is:

- 1 1. (currently amended) A method for correcting signals received from an earth
2 formation using a Nuclear Magnetic Resonance (NMR) tool ~~into~~ in a borehole in
3 said earth formation, the method comprising:
 - 4 (a) exciting said earth formation with a first pulse sequence having a first
5 recovery time;
 - 6 (b) exciting said earth formation with a plurality of additional pulse sequences
7 having a second recovery time less than said first recovery time;
 - 8 (c) determining from spin echo signals resulting from said additional pulse
9 sequences an estimate of a non-formation signal; and
 - 10 (d) correcting spin echo signals resulting from said first pulse sequence using
11 said estimate ~~and obtaining corrected spin echo signals.~~
- 12
- 1 2. (original) The method of claim 1 wherein at least one of said additional pulse
2 sequences has a duration less than a duration of said first pulse sequence.
3
- 1 3. (original) The method of claim 1 wherein said second recovery time corresponds
2 to partial recovery of nuclear spins in said earth formation.
3
- 1 4. (original) The method of claim 1 wherein said additional pulse sequences
2 comprise clay bound water (CBW) sequences.

3

1 5. (original) The method of claim 1 wherein said additional pulse sequences have
2 durations less than 40 ms.

3

1 6. (original) The method of claim 1 wherein said first pulse sequence and said
2 additional pulse sequences comprise CPMG sequences.

3

1 7. (original) The method of claim 1 wherein said first pulse sequence and said
2 additional pulse sequences comprise modified CPMG sequence having a tip angle
3 of a refocusing pulse that is less than 180°.

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1 8. (original) The method of claim 1 wherein said additional pulse sequences
2 comprise pulse sequences having a plurality of pairs of phase alternated pairs
3 (PAP) of pulse sequences.

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1 9. (original) The method of claim 6 wherein said plurality of pairs of PAP sequences
2 have a specified phase relationship to each other.

3

1 10. (original) The method of claim 8 wherein the number of said pairs of PAP
2 sequences nf , frequency shift between said pairs of PAP sequences δf are related
3 according to:

4
$$nf \cdot \delta f = \frac{m}{t}$$

5 where m is any integer that is not a multiple of nf .

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1 11. (original) The method of claim 8 wherein said non-formation signal comprises a
2 ringing from a refocusing pulse.

3

1 12. (original) The method of claim 8 wherein said non-formation signal comprises a
2 ringing from an excitation pulse.

3

1 13. (original) The method of claim 11 wherein estimating said ringing from said
2 refocusing pulse further comprises:

3 (i) separately estimating a ringing from each one of said plurality of phase
4 alternated pairs;

5 (ii) forming a vector sum of said separate estimates.

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1 14. (original) The method of claim 12 wherein estimating said ringing from said
2 excitation pulse further comprises:

3 (i) separately estimating an echo signal from each one of said plurality of
4 phase alternated pairs; and

5 (ii) forming a vector sum of said separate estimates of said echo signal.

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1 15. (currently amended) The method of claim 1 further comprising processing said
2 corrected spin echo signals for determining at least one of (i) a T_2 distribution, (ii)
3 total porosity, (iii) bound volume irreducible, (iv) a T_1 distribution, (v) clay bound
4 water, and, (vi) bound water moveable, and (vii) a sum of echos.

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1 16. (original) The method of claim 1 further comprising conveying said NMR tool
2 into said earth formation on one of (i) a wireline, (ii) a drilling tubular, and, (iii) a
3 slickline.

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1 17. (original) The method of claim 1 further comprising:

2 (i) exciting said earth formation with a second pulse sequence having a
3 recovery time substantially equal to said first recovery time, said second
4 pulse sequence forming a phase alternated pair with said first pulse
5 sequence; and

6 (ii) determining from spin echo signals resulting from said first and second
7 pulse sequences an additional estimate of said non-formation signal.

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1 18. (original) The method of claim 17 further comprising:

2 (A) comparing said estimate and said additional estimate of said non-
3 formation signal; and

4 (B) using a result of said comparison as an indication of a change in said earth
5 formation between positions of said NMR tool at excitation with said first
6 and second pulse sequences.

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1 19. (currently amended) An apparatus for conducting logging operations in a borehole
2 in an earth formation, the apparatus comprising:

- 3 (a) a magnet on a Nuclear Magnetic Resonance (NMR) tool ~~for polarizing~~
4 which polarizes nuclear spins in a region of interest in the earth formation;
5 (b) an antenna on the NMR tool ~~for~~ which:
6 (A) ~~exciting~~ excites said earth formation with a first pulse sequence
7 having a first recovery time;
8 (B) ~~exciting~~ excites said earth formation with a plurality of additional
9 pulse sequences having a recovery time less than said first
10 recovery time;
11 (c) a processor ~~for~~ which:
12 (C) ~~determining~~ determines from spin echo signals resulting from said
13 additional pulse sequences an estimate of a non-formation signal,
14 and
15 (D) ~~correcting~~ corrects spin echo signals resulting from said first pulse
16 sequence using said estimate ~~and obtaining corrected spin echo~~
17 signals.

1 20. (original) The apparatus of claim 19 wherein said additional pulse sequences
2 comprise clay bound water (CBW) sequences.

1 21. (original) The apparatus of claim 19 wherein said additional pulse sequences have
2 durations less than 40 ms.

1 22. (original) The apparatus of claim 19 wherein said first pulse sequence and said
2 additional pulse sequences comprise CPMG sequences.

1 23. (original) The apparatus of claim 19 wherein said first pulse sequence and said
2 additional pulse sequences comprise modified CPMG sequence having a tip angle
3 of a refocusing pulse that is less than 180°.

1 24. (original) The apparatus of claim 19 wherein said additional pulse sequences
2 comprise pulse sequences having a plurality of pairs of phase alternated pairs
3 (PAP) of pulse sequences.

1 25 (original) The apparatus of claim 24 wherein said plurality of pairs of PAP
2 sequences have a specified phase relationship to each other.

1 26 (original) The apparatus of claim 24 wherein the number of said pairs of PAP
2 sequences nf , frequency shift between said pairs of PAP sequences δf are related
3 according to:

4
$$nf \cdot \delta f = \frac{m}{t}$$

5 where m is any integer that is not a multiple of nf .

1 27 (original) The apparatus of claim 24 wherein said non-formation signal comprises
2 a ringing caused by a refocusing pulse.

1 28 (original) The apparatus of claim 24 wherein said non-formation signal comprises
2 a ringing caused by an excitation pulse.

1 29 (currently amended) The apparatus of claim 24 wherein said processor estimates
2 said ringing caused by said an refocusing pulse by:

3 (i) separately estimating a ringing from each one of said plurality of phase
4 alternated pairs;

5 (ii) forming a vector sum of said separate estimates.

1 30 (currently amended) The apparatus of claim 25 wherein said processor estimates
2 said ringing caused by said an excitation pulse by:

3 (i) separately estimating an echo signal from each one of said plurality of
4 phase alternated pairs; and

5 (ii) forming a vector sum of said separate estimates of said echo signal.

1 31 (currently amended) The apparatus of claim 21 wherein said processor further
2 determines from said corrected spin echo signals at least one of (i) a T_2
3 distribution, (ii) total porosity, (iii) bound volume irreducible, (iv) bound water
4 movable, (v) clay bound water, and, (vi) a T_1 distribution, and (vii) a sum of
5 echos.

1 32. (currently amended) The apparatus of claim 19 further comprising a conveyance
2 device for conveying said NMR tool into said borehole, said conveyance device
3 selected from (i) a wireline, (ii) a drilling tubular, and, (iii) a ~~slide line~~ slickline
4

1 33. (currently amended) The apparatus of claim ~~45~~ 19 wherein said transmitter further
2 excites said earth formation with a second pulse sequence having a recovery time
3 substantially equal to said first recovery time, said second pulse sequence forming
4 a phase alternated pair with said first pulse sequence; and wherein said processor
5 further determines from spin echo signals resulting from said first and second
6 pulse sequences an additional estimate of said non-formation signal.
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1 34. (original) The apparatus of claim 33 wherein said processor further:
2 (i) compares said estimate and said additional estimate of said non-
3 formation signal; and
4 (ii) provides an indication of a change in said earth formation between
5 positions of said NMR tool at excitation with said first and second pulse
6 sequences.